CORAL REEF PROJECTS FUNDED BY NSF's BIOLOGICAL OCEANOGRAPHY PROGRAM

Ontogeny and Dynamics of Cnidarian-Algal Symbioses

Mary Alice Coffroth
SUNY Buffalo

Abstract Symbioses between cnidarians and dinoflagellates in the genus Symbiodinium are widespread in the marine environment. Their importance to reef-building corals and reef nutrient cycles is well documented, but surprisingly little is known about the ontogency of the symbiosis and the demographics of zooxanthellae populations within their hosts. An understanding of these processes is essential to understanding the symbiosis. Physiologic adaptations to conditions such as temperature and light may in fact be mediated by the demographics of the algal symbionts. The objective of this research is to determine the ontogeny of the symbiosis in a gorgonian coral that produces a zooxanthellate planulae larvae. Dr. Coffroth will examine initial zooxanthellate infection in planulae larvae and characterized the population structure of the zooxanthellae in established symbioses in adult colonies. These data will determine whether the observed host-algal association are the result of selection (mediated by the host or alga), stochastic process or simply suitability of the host "habitat" to the alga. Understanding the population dynamics of zooxanthellae communities has important ramifications for studying the symbiosis and how the symbiosis responds to environmental changes. It is now recognized that zooxanthellae are a diverse group. If this diversity iswidespread among single host colonies or if the association is in a state of continual flux, then changes in functional and physiologic traits may reflect changes in the algal community structure. In this case it will be critical to examine each component of the symbiosis and consider the population dynamics and ecological responses of both the coral and the algae to understand and preserve reef ecosystems. The first step, however, is to quantify this diversity and address how this diversity is established.

Population and Community Dynamics of Corals: A Long Term Study

Joseph H Connell
U of Cal Santa Barbara

Abstract The objectives of the present project are several: 1) To extend the detailed long-term monitoring of ecological communities of corals and algae on the Great Barrier Reef, Australia which has been carried on continuously over the past 30 years, the longest such study on any coral reef; 2) to expand the study to include sites on two nearby reefs, and additional replicate sites on Heron Reef; 3) to analyze spatial patterns and dynamics of corals and algae at several scales, from centimeters to tens of meters, both during the course of colonization of patches (opened by disturbances) and after most of the surface has become crowded by many colonies. These analyses should reveal the long-term effects of interactions that may be crucial in determining how natural communities are structured; 4) to test with controlled field experiments some hypotheses about mechanisms: a) that produce the unique species composition of corals at the Inner Reef Flat site, b) that cause contrasting patterns of algae after disturbances, and c) that determine precisely how each colony affects its neighbors; 5) to build mathematical models and computer simulations of the dynamics of these populations and communities of corals and algae: a) to investigate the influence of past and present conditions on future changes, b) to characterize temporal and spatial dynamics, and c) to test hypotheses about the consequences of these dynamics to the community. The models will be also used to asses the degree to which community structure and dynamics may or may not be influenced by details of spatial relationships. The field methods will use the standard sampling techniques used over the past 30 years, to assure continuity in the long-term data base. The experimental methods, using coral transplanting and cages to exclude larger herbivores, have also been used before in this study and are well- established. Larval choice experiments and new recruit t ransplants have been carried out successfully by the co- investigators elsewhere on the Great Barrier Reef. The significance of this proposed research to the advancement of knowledge is that: 1) it deepens the general knowledge of how natural communities of corals and algae (the dominant sessile organisms on tropical and sub-tropical reefs), are assembled and structured in the face of changes in their environment over extended periods of time; 2) it reveals some of the mechanisms that link the environment with these community changes, and how both vary over short and long time periods and between small and larger spatial scales; and 3) it helps to predict the effect of environmental changes, including those caused by human activity, on these natural communities.

Coupling Biological and Physical Processes Responsible for Retention of Coral Reef Fish Larvae

Robert K Cowen
University of Miami

Abstract It is widely appreciated that coral reef fish larvae are transported to reef habitats by ocean currents. However, little is known about the behaviors that larval fishes perform to ensure their return to adult habitats. This study will employ an interdisciplinary approach to examine how circulation patterns influence retention and recruitment. Specifically, three-dimensional surveys of larval fish distributions, periodic monitoring of recruitment and detailed measurements of the water flow regime will be conducted in the vicinity of an isolated island (Barbados). Larval fishes will be collected with MOCNESS net tows. Local flow and water column structure will be mapped with ADCP, CTD, current meters and satellite imagery. Data from these tows and instruments will provide a basis for understanding linkages between the intra- and interannual variability of local flow, as well as relationships to the frequency and duration of mesoscale events.

Local Population Dynamics of Temperate and Tropical Reef Fishes at Multiple Scales

Graham E Forrester
U of Cal Los Angeles

Abstract There is considerable debate regarding the major processes that determine population sizes of organisms inhabiting rocky and coral reefs. Most of these organisms have complex life cycles that include widely dispersive propagules and relatively sedentary juveniles and adults, such that the 'birth rate' at a particular reef is equivalent to the rate of settlement of propagules. The controversy focuses on the extent to which supply of propagules vs. post-settlement processes determine local population size and dynamics. To resolve this issue we must know whether, and how, the demographic rates that determine population size at a particular site (settlement, immigration, mortality, and emigration) change with population density (i.e., are the changes in these rates density-dependent). Answering this question is of more than academic interest because, first, it provides the basis for understanding how local population size is regulated naturally, which is essential for effective management of fisheries and other natural populations, and second, it has seldom been answered adequately for any organism. This collaborative research is designed to answer the question of what drives local population dynamics in a comprehensive manner for four species of marine fish inhabiting two very different environments: temperate and tropical reefs. This multi-species, multi-system approach will provide some generality which can perhaps be applied to other marine systems, including demersal and bottom fisheries. Using well-proven methods, the combined experimental and observational design of this study will examine the roles of larval supply, settlement, recruitment, immigration, emigration, competition, and especially predation and its mechanisms, in driving local population dynamics. Results of the field work will be incorporated into mathematical models of population dynamics to provide conceptual generality applicable to other similarly organized systems.

El Nino Impacted Coral Reefs in the Tropical Eastern Pacific: Secondary Disturbances, Recovery and Effects on Community Diversity and Reef Growth

Peter W Glynn
U of Miami Sch Mar&Atmos

Abstract This project will long term study that has focused on ecological disturbances, causes, and the responses of eastern Pacific reef coral populations and reef communities during and following the severe and historically unprecedented 1982 1983 El Nino / Southrn Oscillation (ENSO) event. This study involves strong international collaboration with host country research teams working at several field sites in Costa Rica, Panama, and the Galapagos Islands (Ecuador), all areas that were severely affected during the 1982 1983 ENSO disturbance. This study will continue with (a) monitoring the physical and biological conditions of eastern Pacific coral reefs initiated in the early to mid 1970s, (b) investigating the responses of different coral species to ENSO stressors (chiefly positive sea temperature anomalies) under controlled microcosm conditions, (c) studying coral reproductive ecology as it relates to recruitment success in field surveys, and (d) documenting coral community recovery or changes leading to alternate, non reef building communities. New research directions initiated in

1994 will be pursued, namely (e) an attempt to link coral bleaching/mortality with local and global scale sea surface temperature (SST) anomalies, and (f) modeling the size structure of coral populations and coral community dynamics based on mechanistic relationships between temperature, predation, coral growth, and survivorship derived from field monitoring and experimental results. In addition, (g) analyses of the molecular genetic structure of the different zooxanthella taxa found in eastern Pacific corals to assess the importance of zooxanthellae diversity in explaining the variability in patterns of coral bleaching, and (h) recovering coral populations, to assess their genetic structure and diversity in relationto population size and distance from source populations, will be investigated.

Quantitative Aspects of Prey Chemical Defenses

Mark E Hay
UNC Chapel Hill

Abstract Understanding prey defenses is fundamental to a wide range of ecological and evolutionary topics within marine communities. For example, investigations of differences among species in secondary metabolites, palatability, and susceptibility to consumers have provided insights into factors driving specialization, affecting distribution and community organization, and determining feeding patterns and digestive efficiencies. The proposed research will focus on within-individual differences and the plasticity of individuals to respond to perturbations in their environments.

Local Population Dynamics of Temperate and Tropical Reef Fishes at Multiple Scales

Mark A Hixon
Oregon State University

Abstract There is considerable debate regarding the major processes that determine population sizes of organisms inhabiting rocky and coral reefs. Most of these organisms have complex life cycles that include widely dispersive propagules and relatively sedentary juveniles and adults, such that the "birth rate" at a particular reef is equivalent to the rate of settlement of propagules. The controversy focuses on the extent to which supply of propagules vs. post-settlement processes determine local population size and dynamics. To resolve this issue we must know whether, and how, the demographic rates that determine population size at a particular site (settlement, immigration, mortality, and emigration) change with population density (i.e., are the changes in these rates density-dependent). Answering this question is of more than academic interest because, first, it provides the basis for understanding how local population size is regulated naturally, which is essential for effective management of fisheries and other natural populations, and second, it has seldom been answered adequately for any organism. This collaborative research is designed to answer the question of what drives local population dynamics in a comprehensive manner for four species of marine fish inhabiting two very different environments: temperate and tropical reefs. This multi-species, multi-system approach will provide some generality which can perhaps be applied to other marine systems, including demersal and bottom fisheries. Using well-proven methods, the combined experimental and observational design of this study will examine the roles of larval supply, settlement, recruitment, immigration, emigration, competition, and especially predation and its mechanisms, in driving local population dynamics. Results of the field work will be incorporated into mathematical models of population dynamics to provide conceptual generality applicable to other similarly organized systems.

Molecular analysis of morphologically defined taxa in the Montastraea annularis complex.

Nancy Knowlton
Scripps Institute of Oceanography

Abstract Failure to accurately define and identify species fundamentally compromises our ability to understand and manage marine ecosystems. The problem is particularly acute on reefs, where there is no consensus on the species status of the numerous ecologically and morphologically distinct "forms" that comprise many important groups of corals. While the problematic nature of coral species is widely recognized, there is no consensus as to why this problem exists. Some

scientists argue that extensive and complex patterns of hybridization make species boundaries arbitrary in corals, but the data to test this assertion are largely lacking, particularly for Caribbean corals.

In this project, Dr. Knowlton and collaborators will tackle this problem using the star coral, Montastraea annularis, as a model system. This coral is the most abundant coral of the Caribbean, and has been for millions of years. It has been extensively studied by biologists and geologists as a kind of "lab rat" for a wide variety of studies (e.g. coral bleaching, paleoclimatology), but recent results suggest that what had been viewed as a single polymorphic species may represent a complex of at least three reproductively isolated forms that can be identified by their colony morphologies.

Previous work was on coral genetics, symbiosis, morphometrics and reproductive biology but the genetic patterns on wide geographic scales are of fundamental importance. If the three taxa comprising Montastraea annularis do not routinely interbreed, then fixed diagnostic differences should in principle be detectable. Dr. Knowlton has already uncovered a few fixed or nearly fixed differences using amplified fragment length polyinorphism (AFLP) and restriction fragment length polymorphism (RFLP) between M. faveolata and the other two taxa. She has as yet found no fixed genetic differences between M. annularis and M. franksi, but they appear to spawn at distinct times throughout their range, suggesting that they are not genetically identical. In this project, she will continue to screen for genetic differences among these taxa, in order to determine if hybrids between M. faveolata and the other taxa can be detected and to see if more extensive searches will reveal differences between M. annularis and M. franksi. She will also extend the genetic analyses from Panama to other sites in the Caribbean, to determine if the patterns observed here are also seen elsewhere. This will be the first such genetic analysis of a reef coral species complex throughout its geographic range.

SGER: Population Studies at the Smithsonian Tropical Research Institute San Blas Field Station

Howard R Lasker
SUNY Buffalo

Abstract Population studies of the gorgonian coral Plexaura kuna in the San Blas Point region of Panama have identified patterns of mortality which suggest clone specific sensitivity to environmental stressors. Such patterns are known from laboratory studies and some patterns in nature are consistent with clone specific mortality, but there has not been a demonstration of such patterns being important among natural populations. Such a demonstration is possible among P. kuna populations due to our extensive database on the clonal structure of populations in the San Blas. In order to demonstrate clone specific patterns it will be necessary to resample and analyze many of the populations that were previously surveyed. Such analyses must be undertaken immediately due to the closure of the Smithsonian Tropical Research Institute field station in the San Blas. Immediate sampling is also required in order to characterize the nature and effects of reduced zooxanthellae densities among P. kuna during the onset of 'coral bleaching' that we predict for 1998. Data on zooxanthellae density and reproductive output will be compared from April and June and will be compared with historical samples collected over the past 10 years.

Ultraviolet Radiation on Tropical Reefs: Effects on Fish Vision Coloration and Evolution

George Losey
University of Hawaii

Abstract Ultraviolet radiation is recognized only recently as an important environmental parameter for marine animals. The strong scattering properties of UV light in the sea create unique opportunities for signal detection. It is now known that UV-A radiation (320-400 nni wavelength) is present in a biologically useful intensity up to 400 m deep in clear oceanic water. UV radiation on shallow tropical reefs can be a destructive agent and many reef organisms produce special, UV-absorbing compounds to protect their tissues against radiation damage. Many animals have UV-blocking compounds in their eyes to reduce chromatic aberration and radiation damage and are blind to UV radiation. Recently it was realized that many reef animals lack UV-blocking compounds in their eyes and are sacrificing focusing precision and risking potential damage to their eyes in exchange for the advantages of UV vision. Unique UV-sensitive visual pigments have evolved for the purpose of UV perception. Science knows little about the distribution of this perceptual ability or the form of the UV-perceptual world that may be very different from our own.

This study will explore the UV visual world of reef fishes - a world that is denied to human visual senses. It will examine the hypothesis that the phylogenetic origins of UV vision in fishes centered on detection of pelagic objects such as zooplankton. UV vision while present for food detection, would likely be evolutionarily co-opted for other functions such

as communication. Work will proceed on three fronts. Spectrophotometry will indicate species that lack UV-blocking compounds in their eyes and thus likely have UV vision. UV vision will be confirmed by microspectrophotometry. Using the comparative method, work will study families that include zooplanktivores and other feeding guilds. Species that use UV vision for food detection will likely have other functions such as social communication. Field work with a UV-sensitive underwater video system will describe the fixed and changing UV colorations of fish and their background. Pilot studies have indicated various types of coloration that are not evident in the human-visible spectrum. Some include a complete reversal of the bright/dark reflecting areas that humans perceive. Imaging will concentrate on reef sites such as cleaning stations that are visited by many species that undergo coloration changes during cleaning. Both visible and UV contrast of the colorations that are found will be quantified to explore hypotheses as to the use of UV for close range social communication and longer range broadcast signals. Thirdly, when species are found with interesting UV coloration, field and aquarium studies will establish the likely communication functions of the UV colors.

Understanding both the uses, and phylogenetic distribution, of UV vision and coloration will help us understand the evolution of UV vision and better predict the responses of organisms to changes in UV radiation incident on our oceans. This understanding will also result in better appreciation of the signal detection/transmission value of UV radiation in aquatic media. Knowledge of the existence of unsuspected UV color patterns in the fishes will greatly improve the validity of future studies of the ecology and behavior of these species. At this time, we may literally be "calling black, white!" For species important to commercial and sport fisheries, knowledge of their visual world will impact the design of visual lures as well as visual barriers intended to exclude unwanted "bycatch". It is hoped that the total benefits will rival those that resulted from appreciation of the UV-visual world of terrestrial insects. As an additional benefit, the survey of fish coloration will also result in knowledge of the UV-absorbing characteristics of corals and algae in the environment on a scale that was heretofore impossible. This knowledge may lead to improvement of our understanding, management and conservation of our sustainable shallow reef environments in a world of increasing UV radiation.

Evolution of physical and chemical attributes of gametes in free-spawning marine invertebrates: phylogeny and function.

Richard Miller
Temple University

Abstract The goal of this project is to examine the evolutionary significance of gamete traits that influence fertilization success in free-spawning marine organisms. Basic research in this field is crucial for understanding the reproductive ecology of harvested invertebrates, for aquaculture and for conservation biological reasons. Recent work on the fertilization ecology of free-spawners has raised diverse questions regarding character evolution at the gamete stage of the life cycle. Theory and empirical studies suggest that the size of eggs and egg coats, the density of sperm receptor sites, the speed and longevity of sperm, and the action of sperm-activating compounds released by eggs can each influence fertilization success by affecting rates of sperm-egg contact. These studies, however, have not resolved whether particular traits are a product of selection on fertilization success, and whether such traits appear to co-evolve as a result of their functional interactions.

This project will involve a set of at least 9 sympatric species of marine brittlestars in the genus Macrophiothrix (Echinodermata: Ophiuroidea) from coral reef ecosystems. This group includes at least 40-fold variation in egg volume and provides an ideal comparative system for assessing the importance of size and other gamete attributes in sperm-egg collision. Interest in this genus is especially motivated by our discovery of an unusual degree of species-specificity in sperm chemotaxis, which offers a unique opportunity to examine the role of sperm chemotaxis in promoting reproductive isolation. The research will integrate phylogenetic information, tests of fertilization performance, and measures of gamete attributes to address fundamental questions about the evolution and co-evolution of gamete traits. In order to test hypotheses about gamete function in a phylogenetic context, this study has the following four objectives: OBJECTIVE 1: To construct a phylogeny for the study species using molecular markers. Phylogenetic information is needed to establish historical patterns of character change, as well as to control for correlation among traits due to common ancestry. OBJECTIVE 2: To examine the importance of egg size and other physical gamete attributes in fertilization. In vitro fertilization assays and variation in gamete traits will be used to test the hypothesis that egg target size and sperm swimming speed contribute to interspecific variation in fertilization success. OBJECTIVE 3: To examine the role of spermegg chemical attraction in promoting reproductive isolation. OBJECTIVE 4: To test hypotheses concerning patterns of covariance among gamete traits. Phylogenetic information will be used to test hypotheses of coevolution where theory predicts functional interactions between pairs of traits: ovum size and jelly coat size; egg target size and sperm speed; sperm speed and longevity; egg target size and the strength of sperm chemotaxis.

This research is designed to fill critical gaps in our understanding of fertilization ecology and the evolution of gamete characters. This will be a comprehensive study in a phylogenetic context of both physical and chemical traits that

can influence rates of gamete contact . By using phylogenetic information for a closely-related group of ecologically similar organisms, this research explicitly tests evolutionary hypotheses about functional relationships among such traits. Furthermore, the unique pattern of sperm chemotaxis in this system provides an opportunity to examine the role of pre-contact chemical specificity in promoting the reproductive isolation of synchronously-spawning species. Because free-spawning is the dominant and likely ancestral mode of fertilization, results from this project will have widespread relevance to the evolution of reproductive systems in marine environments.

Biochemical Control of Larval Settlement and Recruitment of the Major Reef-Building Coral, Acropora Palmata

Daniel E Morse, Peter T Raimondi & Aileen Morse
U of Cal Santa Barbara

Abstract The goal of the research is to determine whether molecular signals and mechanisms similar to those that control larval settlement, metamorphosis and recruitment of the Agariciid corals also regulate these centrally important processes in Acropora palmata, one of the most ecologically important, abundant and rapidly growing major reef-building corals of the Caribbean. This question is of major ecological significance because A. palmata is representative of the most specious genus of corals on Earth, and is representative of the ecologically dominant corals that reproduce by synchronous mass spawning to yield larvae that lack endosymbiotic algae (zooxanthellae). The corals in which signal-dependent induction of larval settlement and recruitment previously had been demonstrated (the Agariciid corals) reproduce by brooding and release of mature larvae that already contain endosymbiotic zooxanthellae, and these corals often play relatively minor ecological roles in the natural environment. Following up on recent research leads, the specific objectives of the proposed renewal are to test the following specific hypotheses: (1) That specific crustose coralline algae are required to induce larval settlement and metamorphosis of the mass-spawning A. palmata; (2) That chemosensory recognition mediates larval responsiveness to any such required substratum; (3) That the molecular inducer of settlement and metamorphosis recognized by A. palmata larvae is an algal (or microbial) cell- wall compound identical or closely similar to that which controls larval settlement, metamorphosis and recruitment of the sympatric Agariciids; (4) That larval recognition of this inducer molecule (purified and immobilized on a "larval flypaper") can be shown to be responsible, in part, for substratum-specific settlement, metamorphosis and recruitment of A. palmata in the natural environment; and (5) That species-specific differences in larval orientation at settlement reduce the potential for competition between Acropora palmata and Agaricia humilis.

Evolution of physical and chemical attributes of gametes in free-spawning marine invertebrates: phylogeny and function.

Robert Podolsky
University of North Carolina

The goal of this project is to examine the evolutionary significance of gamete traits that influence fertilization success in free-spawning marine organisms. Basic research in this field is crucial for understanding the reproductive ecology of harvested invertebrates, for aquaculture and for conservation biological reasons. Recent work on the fertilization ecology of free-spawners has raised diverse questions regarding character evolution at the gamete stage of the life cycle. Theory and empirical studies suggest that the size of eggs and egg coats, the density of sperm receptor sites, the speed and longevity of sperm, and the action of sperm-activating compounds released by eggs can each influence fertilization success by affecting rates of sperm-egg contact. These studies, however, have not resolved whether particular traits are a product of selection on fertilization success, and whether such traits appear to co-evolve as a result of their functional interactions.

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Microstructure in Modern Marine Stromatolites: A Geomicrobiological Investigation of Processes Forming Lithified Miciritic Laminae

R. Pamela Reid
U of Miami Sch Mar&Atmos

This project will determine the origin of microcrystalline carbonate in stromatolites: is it precipitation resulting from bacterial metabolic activity, or physical trapping of resuspended particles? Crusting and “soft” mats from Exuma Cays, Bahamas, will be compared, with experimental intervention to encourage or inhibit lithification. Analyses will include structure and mineralogy of grains, structure of microbe community, mat physiology, and biogeochemistry of stable isotopes and extracellular secretions.

SGER: Enhance Research Capabilities at Carrie Bow Cay Field Station,Belize

Klaus Ruetzler & Marsha F Sitnik
Smithsonian Institution, Washington, DC

Abstract This small award will allow the Caribbean Coral Reef Ecosystems Program and its lab in Belize to acquire a small research boat to accommodate visiting scientists working in the coral reef, seagrass and mangrove systems of the Belizean barrier reef complex. This will allow scientists at the lab to optimize their investigations of coral bleaching in the Belize barrier reef complex as well as to accommodate studies of the possible responses to ENSO perturbations. The NSF supports many scientists using the CCRE lab for short- term experimental studies and excellent field access. The new vessel will improve the capability of the lab and will facilitate many research projects.

On the Abundance, Dynamics and Regulation of Damselfish Populations

Russell J Schmitt & Sally J Holbrook
U of Cal Santa Barbara

Abstract The aim of the work is to understand the dynamics and regulation of structured, open populations, which typify most marine reef fishes and invertebrates. While there is broad agreement among ecologists that attributes of populations are shared by more than an single process (e.g., availability of propagules, competition within and between life stages, competition with other species, predation), there remains considerable disagreement regarding their relative importance. There also is some confusion about what roles various processes have in producing dynamics; few empirical workers have distinguished between processes that regulate populations (i.e., bound fluctuations) as opposed to those that cause variation around the mean abundance. An enormous amount is known about the caused of fluctuations in abundance of reef organisms,

but very little is known about what regulates their populations. This work will contribute in several key ways to understanding the general issue of dynamics and regulation. It is one of the first comprehensive, pluralistic evaluations of reef fishes that will distinguish effects of processes on regulation and on variation. Second, it will use for the first time operational definitions and analytical protocols for quantitative assessments of the relative importance of various processes. As such, the research could yield standard approaches and procedures to address relative importance. Third, the application of infrared video technology enables the exploration of little studied but crucial processes of settlement and early mortality.

Nutrition of reef corals: effects of morphology, resource availability, and water flow.

Kenneth Sebens
University of Maryland

Abstract Coral reef ecosystems depend on water movement at all levels. Water movement delivers prey to corals and enhances uptake and exchange of nutrients, oxygen, carbon dioxide, bicarbonate and other ions. It also affects coral competition, larval dispersal, fragmentation, activity of predators, and sedimentation, thus having a large potential impact on coral distribution. Flow micro-habitats on reefs differ substantially, even over a few meters or less, causing measurable differences in coral growth rates. The contribution of zooxanthellae (photosynthesis) to coral energetics is most strongly affected by diffusional limitations at the lower extremes of flow, modified by changes in irradiance. Flow at the smallest scale affects the processes of respiration, productivity and suspension feeding by corals, the escape behavior of zooplankton encountering corals, and the ultimate success of particular polyp, tentacle, and colony morphologies.

Over an entire reef, there is a characteristic gradient from high velocity oscillatory (wave-induced) flow in shallow reef zones, to unidirectional flows of lower velocity in deep reef and lagoonal habitats. Such flow regimes affect benthic-pelagic fluxes and dispersal of gametes and larvae of reef dwelling species. Corals vary in polyp size, tentacle form and colony structure; coral growth forms in each reef zone reflect adaptations to local flow and light regimes at the polyp and colony levels.

In this project Dr. Sebens, collaborators and students will investigate the effects of water movement on the feeding biology, energetics, and nutrition of reef corals. Attempts to model energy, carbon and nitrogen budgets have suffered from a lack of information on prey capture rates and have generally not considered flow effects adequately. Past studies along with new data on the contributions of sediment ingestion and inorganic nutrient uptake to energy, carbon, and nitrogen requirements will be used to construct energy, carbon, and nitrogen budgets for at least six coral species. Effects of water flow on each input and output process will be incorporated into this model budget. The project will continue to measure small scale water flow around corals in the field. Self-contained underwater flowmeters with fine spatial resolution have been constructed for this research. The data collected will be used to characterize the general flow regime, providing new information about the flow environment of coral reefs in Jamaica, Florida, Belize and other sites in the Caribbean. This new information on coral feeding with flow will extend the current conceptual model to encompass a diversity of colony forms, tentacle morphologies, and nematocyst compositions. Zooplankton feeding by coral reef cnidarians is necessary for their survival, yet most studies have focused on the autotrophic contribution from their endosymbiotic zooxanthellae. This research will increase our understanding of energy and nutrient fluxes in coral reef environments, which are among the most productive and endangered marine habitats.

PECASE: Effects of Morphology and Water Velocity on Mass Transfer: A Partnership in Research and Education

Florence I. M Thomas
Marine Envrnmtl Sci Conso- Dauphin Island

Abstract This program combines research in biomechanics with an education component linking public, K-12, undergraduate, and graduate education. The research addresses how the morphology of the predominate organisms in a community affects biological processes at the scale of the whole community rather than the scale of the individual. Rates of nutrient uptake by whole communities, that vary in flexibility and morphology, will be measured over a range of water velocity in a research

flume. Comparisons of measured uptake rates with those calculated using empirically derived equations, describing mass transfer to non-biotic surfaces, will be made to parameterize mass transfer relationships for biotic surfaces. The results can be applied to other problems concerning rates of transport within communities, such as feeding, fertilization success, and the transport of other dissolved compounds such as pollutants. The education component of the program includes: 1) the development of an interactive display in a public aquarium to interpret flume experiments for visitors and K-12 education programs; 2) research fellowships for minority students; and 3) incorporation of biomechanics/ hydrodynamics into undergraduate courses.